IL REPORT NACA TR 572

Le ali hanno la forma in pianta le più disparate, ma quelle più comuni hanno la forma in pianta trapezia. Quest'ala può essere geometricamente individuata da due parametri: allungamento e il rapporto di rastremazione. Nel caso in cui le estremità siano arrotondate si procede come in FIG.1. per calcolare il rapporto di rastremazione.

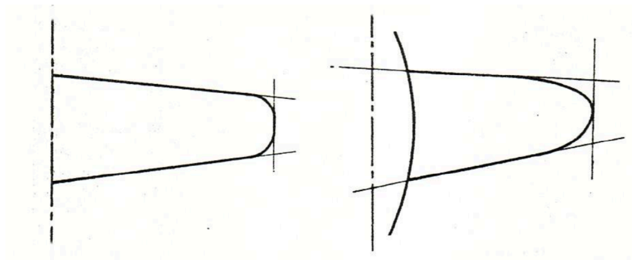


Figura 1 - Spesso le ali presentano le estremità arrotondate

Questi tipi di ali possono essere studiate con i metodi di Prandtl, come è stato fatto nel report NACA TR 572.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

REPORT No. 572

DETERMINATION OF THE CHARACTERISTICS
OF TAPERED WINGS

By RAYMOND F. ANDERSON

REPRINT OF REPORT No. 572, ORIGINALLY PUBLISHED FEBRUARY 1937

Gli autori del report sono Raymond e Anderson ed è grazie ai loro calcoli che possiamo rapidamente dedurre quanto interessa conoscere dal punto di vista aerodinamico su un'ala che rientri nei limiti, molto ampi, di validità del report; i risultati sono stati rappresentati per via grafica o tabellare.

Qualunque sia l'ala, la distribuzione di portanza può essere considerata composta da due parti:

1) DISTRIBUZIONE DI PORTANZA BASICA – che dipende dallo svergolamento e dà risultante nulla
2) DISTRIBUZIONE DI PORTANZA ADDIZIONALE – che dipende dall'angolo di incidenza.

Noti questi diagrammi di portanza, si è in grado di determinare la distribuzione effettiva procedendo per somma.

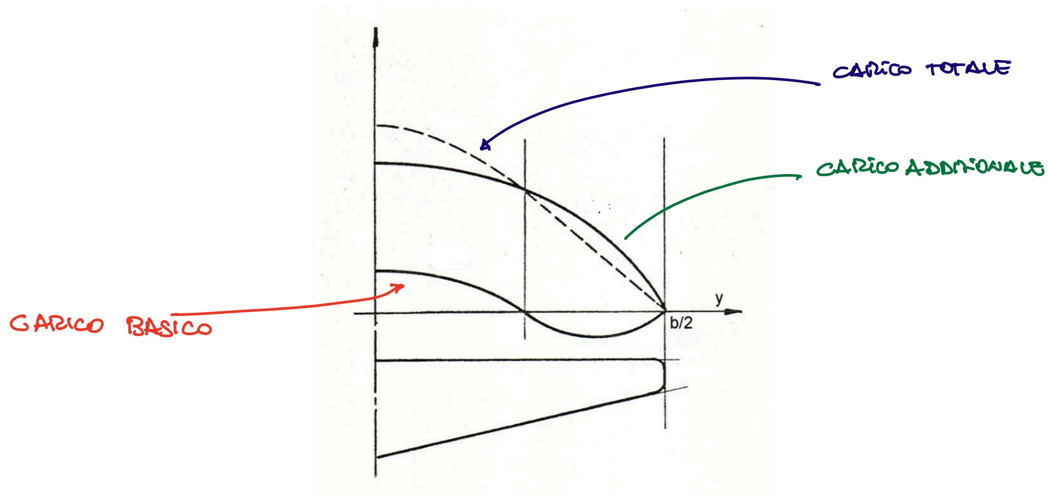


Figura 2 - Distribuzione di portanza in apertura

Le espressioni per il calcolo delle due distribuzioni di portanza sono:

$$\boxed{C_l|_a\, c = \frac{S}{b} L_a C_L} \quad ; \quad \boxed{C_l|_b\, c = \frac{S}{b}\, \varepsilon\, C_{l_\alpha} L_b}$$

dove L_a e L_b sono numeri che si ricavano dalle tabelle in APPENDICE in funzione dell'allungamento AR, di $y/(b/2)$ e del rapporto di rastremazione $r = c_t/c_s$.

Il report NACA TR 572 non si limita a fornire la distribuzione di portanza lungo l'apertura alare, ma permette il calcolo dell'inclinazione della curva della retta di portanza (a) e del coefficiente di resistenza indotta (C_{D_i})

$$a = f\,\frac{a_0}{1 + \frac{57.3\, a_0}{\pi AR}} \quad ; \quad C_{D_i} = \frac{C_L^2}{\pi AR\, u} + C_L\, \varepsilon\, a_0\, v + (\varepsilon a_0)^2 w$$

(a_0 è l'angolo di attacco del profilo)

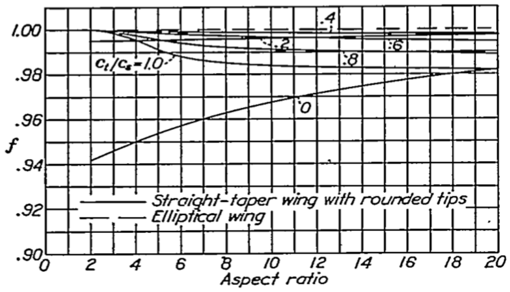


FIGURE 2.—Chart for determining lift-curve slope.

$$a = f\frac{a_0}{1+\frac{57.3\,a_0}{\pi A}} \qquad m = 57.3a$$

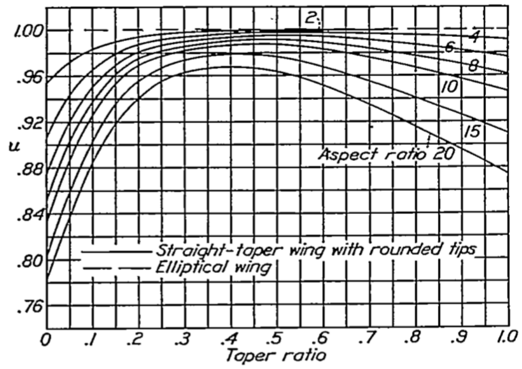


FIGURE 4.—Chart for determining induced-drag factor u.

$$C_{D_i} = \frac{C_L^2}{\pi A u} + C_L \epsilon a_0 v + (\epsilon a_0)^2 w$$

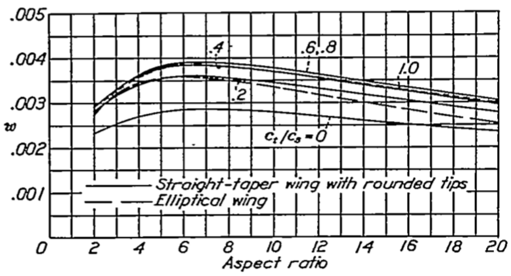


FIGURE 6.—Chart for determining induced-drag factor w.

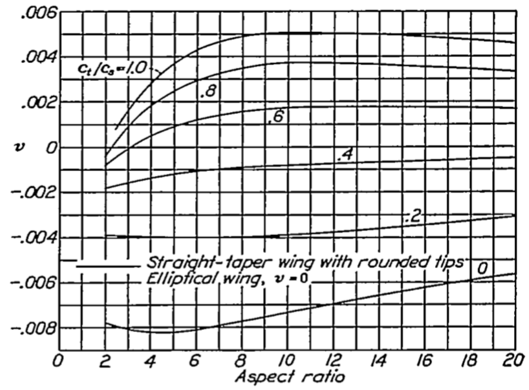


FIGURE 5.—Chart for determining induced-drag factor v.

Il report, inoltre, consente di calcolare l'angolo di portanza nulla

$$\alpha_{S|_{L=0}} = \alpha_{L_0 S} + J\,\varepsilon^{(rad)}$$

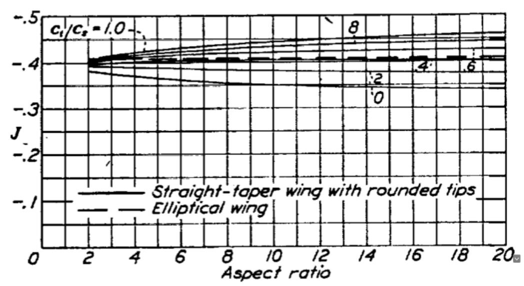


FIGURE 3.—Chart for determining angle of attack.

$$\alpha_s = \frac{C_L}{a} + \alpha_{l_{0_s}} + J\epsilon \qquad \alpha_{s(L=0)} = \alpha_{l_{0_s}} + J\epsilon$$

Come riferimento si considera la sezione di mezzeria; l'incidenza dell'ala è l'angolo che la V_∞ forma con la corda di mezzeria. Nella formula compare

α_{los} che è l'angolo di incidenza nulla in memoria; ε è lo svergolamento mentre J è un coefficiente tabulato in FIGURA 3.
Il report permette di determinare il coefficiente di momento focale in base alla formula:

$$C_M = E\, C_{M_F} - G\, \alpha\, C_{l_\alpha}\, AR\, tg\beta$$

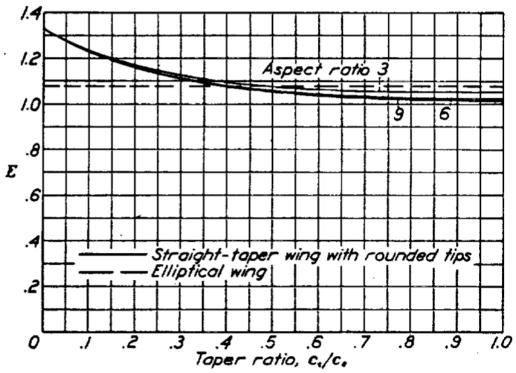


FIGURE 7.—Chart for determining pitching moment due to section moment.
$C_{m_s} = E c_{m_{a.c.}}$.
For $c_{m_{a.c.}}$ constant across the span.

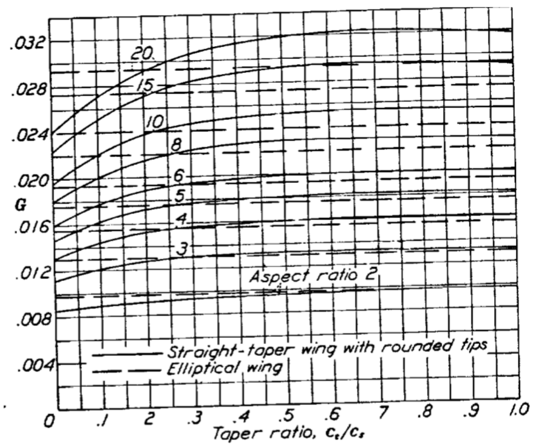


FIGURE 8.—Chart for determining pitching moment due to basic lift forces.
$C_{m_{l_b}} = -G e a_0 A \tan\beta$.

È possibile, ancora, determinare la posizione del fuoco:

$$\frac{x_F}{S/b} = H\, AR\, tg\beta$$

dove con x_F si è indicata la posizione del fuoco della stazione di memoria, AR è l'allungamento alare e β è l'angolo di freccia. H è rappresentato in figura.

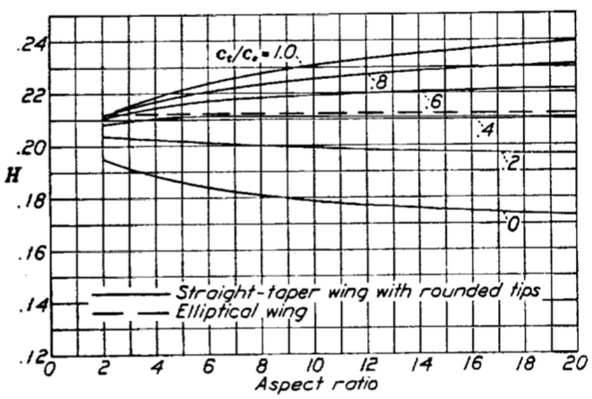


FIGURE 9.—Chart for determining aerodynamic-center position.

$\frac{x_{a.c.}}{S/b} = HA \tan\beta$.

Si sviluppano alcune importanti considerazioni sullo svergolamento in quanto questo è un mezzo potente per modificare la distribuzione di portanza lungo l'apertura. In particolare "giocando" con lo svergolamento si cerca di spostare il punto di inizio stallo verso la mezzeria allontanandolo dalle estremità dove sono situati gli alettoni i quali verrebbero messi in ombra; inoltre agendo sullo svergolamento è possibile ottenere una distribuzione di portanza lungo l'apertura vicina a quella ellittica, cui corrisponde la minima resistenza indotta.

Raymond e Anderson nel loro report forniscono un metodo efficace e ingegnoso per verificare le condizioni di stallo. Mediante le tabelle contenute nel report si tracciano le due distribuzioni di portanza e quindi per somma la distribuzione totale; si riporta anche il diagramma di $C_{l\max} c$; tale diagramma è immediato nel caso in cui il profilo è costante.

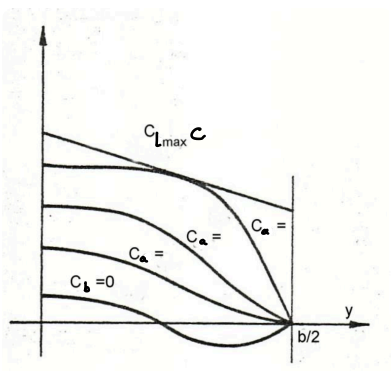
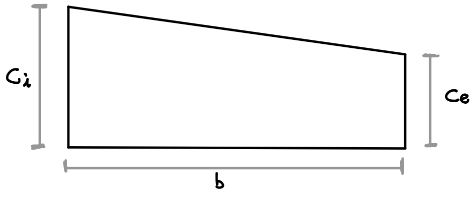


Figura 11 - Distribuzione di portanza in apertura in funzione dei coefficienti di portanza dell'ala

Si tracciano le varie curve di $C_l c$ al variare di C_L; si trova una di queste tangente alla curva $C_{l\max} c$; si sono determinati il coefficiente massimo di portanza dell'ala e il punto su cui ha inizio lo stallo (p.to di tangenza).

ESERCIZIO - Tracciare la distribuzione di portanza lungo l'apertura applicando il metodo di Anderson per un'ala avente apertura alare $b = 5{,}87$ m, corda all'incastro $c_i = 1.6$ m, corda all'estremità $c_e = 0.75$ m e svergolamento $\varepsilon = -3°$. Assumendo inoltre un $C_{l\max}$ del profilo uguale a 1.2 determinare il $C_{L\max}$ dell'ala e il punto geometrico di inizio stallo.

SVOLGIMENTO - Calcoliamo i dati geometrici dell'ala.



$$S = \frac{(c_i + c_e) \times b}{2} = \frac{(1.6 + 0.75) \times 5.87}{2} = 6{,}9\ m^2$$

$$C_{L\alpha} = 5.73\ ;\quad b = 5.87\ ;\quad AR = \frac{b^2}{S} \cong 5$$

$\frac{S}{b} = 1.175m$; $\varepsilon = -3° = -0.052$ rad ; $r = \frac{Ce}{Ci} = \frac{0.75}{1.60} = 0.47 \simeq 0.5$

Le espressioni per il calcolo delle due distribuzioni di portanza (la basica e l'addizionale) sono:

$\boxed{C_{la} \cdot c = \frac{S}{b} L_a C_l} \Rightarrow \boxed{C_{l_a} \cdot c = 1.175 \; L_a C_l}$

$\boxed{C_{l_b} \cdot c = \frac{S}{b} \varepsilon C_{l\alpha} L_b} \Rightarrow \boxed{C_{L_b} \cdot c = -1.175 \cdot 0.052 \cdot 5.73 \cdot L_B = -0.35 \cdot L_B}$

Distribuzione di portanza lungo l'apertura

y/(b/2)	y	Lb	La	CLb*c	CLa*c/CL	per CL=1 / CLtot*c	per CL=1.2 / CLtot*c
0	0	-0,225	1,301	0,0788	1,5287	1,607	1,913
0,2	0,587	-0,158	1,240	0,0553	1,4570	1,512	1,804
0,40	1,174	-0,018	1,142	0,0063	1,3419	1,348	1,617
0,60	1,761	0,091	1	-0,0319	1,1750	1,143	1,378
0,80	2,348	0,143	0,769	-0,0501	0,9036	0,854	1,034
0,90	2,642	0,140	0,583	-0,0490	0,6850	0,636	0,773
0,95	2,788	0,112	0,436	-0,0392	0,5123	0,473	0,576
0,97	2,847	0,075	0,32	-0,0263	0,3760	0,350	0,425
1	2,935	0	0	0,0000	0,0000	0,000	0,000

Si traccia poi la retta di stallo, tenendo presente che:

all'incastro : $C_{l_{max}} \times c = 1.2 \times 1.6 = 1.92$

all'estremità : $C_{l_{max}} \times c = 1.2 \times 0.75 = 0.90$

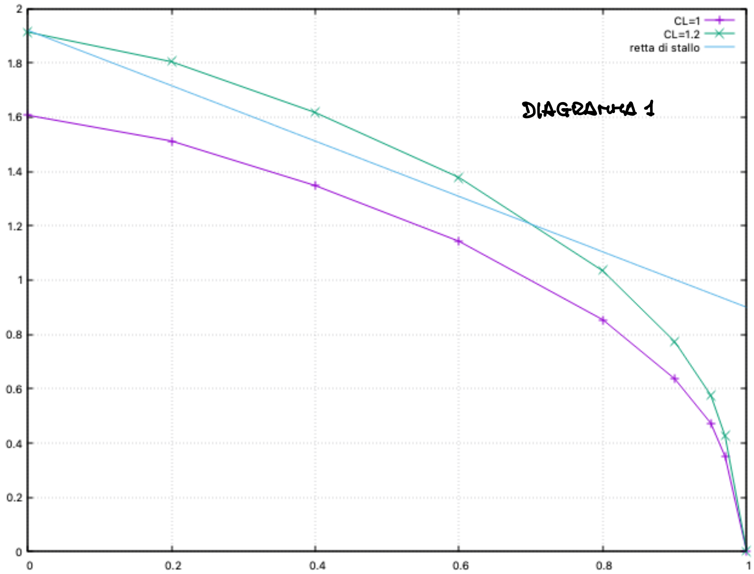
La retta $y = mx + q$ per $x=0$ deve valere 1.92 e per $x=1$ deve valere, invece, 0.90. Quindi:

$$\begin{cases} 1.92 = q \\ 0.90 = m + q \end{cases} \rightarrow 0.90 = m + 1.92 \rightarrow m = 0.90 - 1.92 \rightarrow m = -1.02$$

Quindi è:

$$y = -1.02x + 1.92$$

Dal DIAGRAMMA 1 si nota che il $C_{l_{max}}$ dell'ala è compreso tra $C_L = 1$ e $C_L = 1.2$.

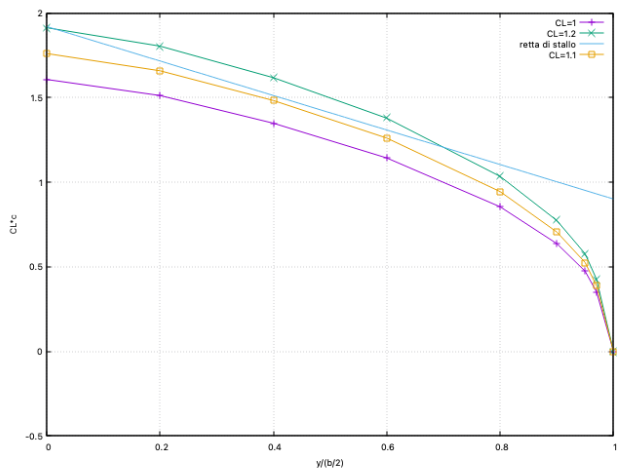


Per $C_L = 1.1$ è:

Distribuzione portanza lungo l'apertura

y/(b/2)	Lb	La	CLb*c	CLa*c/CL	per CL=1.1 / CLtot*c
0	-0.225	1.301	0.0788	1.5287	1.7603
0.2	-0.158	1.240	0.0553	1.4570	1.6580
0.40	-0.018	1.142	0.0063	1.3419	1.4823
0.60	0.091	1	-0.0319	1.1750	1.2607
0.80	0.143	0.769	-0.0501	0.9036	0.9439
0.90	0.140	0.583	-0.0490	0.6850	0.7045
0.95	0.112	0.436	-0.0392	0.5123	0.5243
0.97	0.075	0.32	-0.0263	0.3760	0.3874
1	0	0	0.0000	0.0000	0.0000

Si deduce che il $C_{L\,max}$ dell'ala è 1.1 e l'ala inizia a stallare intorno al 60% della apertura alare.



APPENDICE

TABLE I.—BASIC SPAN LIFT-DISTRIBUTION DATA

VALUES OF L_b FOR TAPERED WINGS WITH ROUNDED TIPS $c_{l_b}=\frac{\epsilon a_0 S}{cb}L_b$

A \ c_t/c_s	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	SPANWISE STATION $\frac{y}{b/2}=0$										
2	−0.118	−0.121	−0.122	−0.122	−0.122	−0.121	−0.121	−0.121	−0.120	−0.120	−0.120
3	−.153	−.160	−.162	−.163	−.165	−.164	−.164	−.163	−.162	−.161	−.160
4	−.183	−.192	−.197	−.199	−.199	−.199	−.198	−.197	−.196	−.194	−.192
5	−.211	−.221	−.224	−.226	−.225	−.225	−.224	−.224	−.221	−.219	−.218
6	−.235	−.248	−.253	−.253	−.252	−.252	−.250	−.247	−.244	−.243	−.242
7	−.256	−.269	−.275	−.276	−.274	−.272	−.270	−.268	−.264	−.261	−.258
8	−.274	−.288	−.293	−.293	−.291	−.290	−.288	−.285	−.282	−.279	−.276
10	−.304	−.318	−.322	−.323	−.321	−.320	−.318	−.315	−.311	−.305	−.299
12	−.329	−.342	−.350	−.349	−.348	−.345	−.341	−.337	−.331	−.323	−.317
14	−.350	−.364	−.370	−.370	−.368	−.365	−.360	−.355	−.350	−.342	−.334
16	−.367	−.380	−.386	−.385	−.382	−.379	−.375	−.370	−.362	−.358	−.348
18	−.384	−.399	−.405	−.403	−.400	−.393	−.387	−.380	−.376	−.368	−.360
20	−.398	−.411	−.417	−.415	−.410	−.404	−.399	−.392	−.386	−.378	−.369
	SPANWISE STATION $\frac{y}{b/2}=0.2$										
2	−0.076	−0.080	−0.082	−0.085	−0.086	−0.086	−0.086	−0.085	−0.085	−0.084	−0.083
3	−.098	−.108	−.111	−.112	−.113	−.113	−.113	−.113	−.112	−.110	−.108
4	−.117	−.130	−.135	−.138	−.137	−.137	−.137	−.137	−.137	−.135	−.132
5	−.131	−.148	−.156	−.159	−.159	−.158	−.158	−.158	−.157	−.156	−.152
6	−.145	−.162	−.173	−.176	−.176	−.176	−.176	−.176	−.175	−.172	−.170
7	−.156	−.178	−.189	−.192	−.192	−.192	−.191	−.191	−.190	−.190	−.189
8	−.168	−.189	−.200	−.204	−.204	−.205	−.205	−.206	−.205	−.204	−.204
10	−.182	−.207	−.220	−.224	−.225	−.225	−.226	−.226	−.225	−.225	−.225
12	−.197	−.226	−.239	−.240	−.239	−.238	−.238	−.238	−.237	−.237	−.237
14	−.206	−.234	−.248	−.249	−.248	−.248	−.248	−.248	−.248	−.248	−.248
16	−.212	−.242	−.256	−.258	−.257	−.256	−.256	−.256	−.256	−.256	−.255
18	−.219	−.247	−.260	−.264	−.265	−.265	−.265	−.265	−.265	−.264	−.262
20	−.222	−.255	−.269	−.271	−.271	−.271	−.272	−.272	−.272	−.272	−.270
	SPANWISE STATION $\frac{y}{b/2}=0.4$										
2	−0.006	−0.011	−0.013	−0.015	−0.016	−0.016	−0.016	−0.016	−0.016	−0.016	−0.015
3	−.002	−.010	−.012	−.015	−.016	−.016	−.016	−.016	−.017	−.018	−.018
4	0	−.006	−.011	−.012	−.016	−.016	−.018	−.019	−.020	−.020	−.021
5	.004	−.004	−.010	−.012	−.016	−.018	−.020	−.021	−.021	−.022	−.023
6	.009	−.002	−.008	−.012	−.016	−.018	−.020	−.021	−.022	−.024	−.026
7	.012	−.001	−.010	−.013	−.017	−.018	−.020	−.022	−.025	−.027	−.029
8	.014	0	−.008	−.012	−.017	−.019	−.021	−.025	−.029	−.030	−.030
10	.021	.007	−.002	−.010	−.017	−.020	−.022	−.027	−.030	−.032	−.032
12	.028	.009	−.001	−.010	−.017	−.021	−.025	−.029	−.032	−.036	−.038
14	.036	.013	0	−.010	−.017	−.021	−.028	−.031	−.035	−.040	−.042
16	.043	.019	.002	−.008	−.016	−.022	−.029	−.034	−.038	−.041	−.045
18	.049	.022	.004	−.008	−.015	−.022	−.031	−.038	−.041	−.043	−.046
20	.050	.023	.006	−.006	−.014	−.023	−.031	−.038	−.041	−.046	−.049

TABLE I.—BASIC SPAN LIFT-DISTRIBUTION DATA—Continued

VALUES OF L_b FOR TAPERED WINGS WITH ROUNDED TIPS $c_{l_b}=\frac{ea_0S}{cb}L_b$

A \ c_t/c_s	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	SPANWISE STATION $\frac{y}{b/2}=0.6$										
2	0.052	0.053	0.051	0.050	0.050	0.050	0.050	0.050	0.049	0.049	0.048
3	.070	.069	.068	.068	.068	.068	.068	.068	.068	.068	.068
4	.085	.082	.081	.080	.080	.080	.080	.080	.080	.080	.080
5	.099	.095	.092	.091	.091	.091	.091	.091	.090	.090	.090
6	.109	.107	.104	.102	.101	.101	.100	.100	.100	.100	.100
7	.119	.117	.114	.112	.111	.110	.110	.110	.110	.109	.108
8	.128	.122	.121	.120	.120	.119	.119	.118	.118	.117	.116
10	.139	.138	.135	.132	.131	.130	.130	.129	.128	.126	.124
12	.148	.145	.141	.140	.140	.139	.137	.135	.134	.132	.130
14	.155	.152	.150	.148	.145	.142	.141	.140	.139	.138	.135
16	.160	.158	.154	.151	.149	.146	.143	.141	.140	.139	.136
18	.165	.162	.160	.158	.152	.148	.145	.142	.140	.139	.138
20	.170	.169	.165	.159	.152	.148	.147	.143	.141	.140	.140
	SPANWISE STATION $\frac{y}{b/2}=0.8$										
2	0.072	0.079	0.080	0.082	0.083	0.085	0.085	0.086	0.086	0.084	0.081
3	.088	.098	.101	.102	.104	.108	.109	.110	.110	.108	.106
4	.100	.113	.120	.123	.125	.128	.128	.130	.130	.130	.129
5	.109	.125	.135	.138	.140	.143	.147	.148	.148	.148	.149
6	.115	.135	.148	.152	.156	.160	.160	.162	.163	.164	.165
7	.121	.142	.158	.163	.169	.172	.173	.173	.174	.174	.175
8	.126	.149	.164	.174	.180	.182	.182	.183	.183	.184	.184
10	.136	.160	.178	.188	.195	.200	.201	.202	.203	.201	.198
12	.145	.170	.188	.200	.208	.212	.214	.216	.216	.214	.210
14	.152	.182	.200	.210	.216	.221	.223	.227	.228	.225	.220
16	.159	.186	.205	.216	.222	.229	.232	.233	.236	.232	.229
18	.161	.197	.215	.224	.230	.235	.239	.242	.243	.242	.238
20	.166	.201	.220	.232	.237	.241	.245	.248	.248	.248	.247
	SPANWISE STATION $\frac{y}{b/2}=0.9$										
2	0.059	0.068	0.072	0.073	0.075	0.076	0.075	0.075	0.075	0.075	0.075
3	.068	.083	.092	.098	.099	.100	.100	.100	.100	.100	.100
4	.074	.098	.111	.118	.121	.122	.123	.123	.123	.123	.123
5	.081	.107	.122	.131	.138	.140	.141	.141	.142	.142	.142
6	.087	.117	.136	.148	.154	.159	.160	.160	.160	.160	.160
7	.090	.123	.146	.160	.167	.171	.171	.172	.172	.172	.172
8	.092	.131	.153	.170	.179	.182	.183	.184	.185	.186	.187
10	.098	.139	.166	.184	.197	.201	.203	.205	.207	.209	.210
12	.100	.147	.178	.198	.210	.218	.221	.225	.228	.229	.230
14	.102	.156	.188	.208	.220	.231	.238	.241	.243	.245	.246
16	.103	.161	.197	.219	.231	.241	.249	.253	.258	.259	.260
18	.105	.166	.202	.228	.243	.252	.260	.263	.269	.271	.275
20	.107	.172	.211	.233	.248	.260	.268	.273	.279	.282	.285
	SPANWISE STATION $\frac{y}{b/2}=0.95$										
2	0.038	0.051	0.058	0.059	0.060	0.060	0.060	0.060	0.059	0.059	0.058
3	.044	.063	.073	.078	.079	.080	.080	.080	.080	.079	.078
4	.050	.072	.076	.092	.095	.097	.099	.100	.100	.100	.099
5	.052	.083	.100	.107	.110	.112	.113	.114	.116	.117	.116
6	.054	.088	.109	.119	.122	.128	.130	.132	.132	.131	.130
7	.056	.093	.116	.130	.135	.140	.144	.148	.150	.149	.145
8	.057	.100	.125	.140	.146	.152	.158	.160	.161	.160	.159
10	.058	.107	.138	.152	.162	.171	.178	.182	.186	.187	.183
12	.059	.112	.143	.165	.179	.189	.198	.200	.202	.205	.204
14	.060	.116	.151	.174	.190	.202	.211	.215	.218	.221	.222
16	.061	.121	.159	.184	.203	.218	.222	.229	.233	.236	.238
18	.061	.126	.166	.194	.213	.229	.236	.241	.248	.251	.255
20	.061	.128	.173	.203	.225	.239	.245	.251	.259	.265	.271
	SPANWISE STATION $\frac{y}{b/2}=0.975$										
2	0.019	0.030	0.035	0.037	0.037	0.037	0.037	0.036	0.036	0.035	0.034
3	.022	.039	.045	.049	.050	.051	.052	.054	.053	.052	.051
4	.026	.043	.054	.060	.062	.064	.068	.069	.069	.068	.067
5	.029	.051	.065	.070	.071	.075	.078	.081	.082	.083	.083
6	.030	.055	.071	.079	.082	.088	.091	.094	.097	.097	.097
7	.030	.060	.078	.087	.091	.098	.101	.107	.110	.110	.110
8	.030	.062	.081	.091	.100	.107	.112	.120	.121	.121	.121
10	.031	.067	.090	.105	.115	.124	.132	.138	.141	.142	.143
12	.031	.060	.095	.115	.131	.141	.149	.153	.160	.161	.162
14	.031	.071	.102	.127	.143	.155	.163	.171	.175	.177	.178
16	.031	.077	.111	.138	.156	.169	.178	.182	.188	.190	.191
18	.032	.083	.121	.150	.169	.182	.191	.197	.200	.201	.202
20	.032	.086	.128	.158	.178	.193	.202	.208	.210	.212	.213

TABLE II.—ADDITIONAL SPAN LIFT-DISTRIBUTION DATA

VALUES OF L_a FOR TAPERED WINGS WITH ROUNDED TIPS, $c_{l_{a1}}=\frac{S}{cb}L_a$

c_t/c_s / A	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	SPANWISE STATION $\frac{y}{b/2}=0$										
2	1.439	1.400	1.367	1.339	1.316	1.301	1.298	1.292	1.290	1.287	1.282
3	1.489	1.430	1.385	1.350	1.322	1.302	1.288	1.275	1.263	1.253	1.246
4	1.527	1.452	1.400	1.360	1.329	1.302	1.279	1.260	1.242	1.226	1.211
5	1.559	1.473	1.414	1.369	1.333	1.301	1.272	1.248	1.225	1.204	1.186
6	1.585	1.492	1.428	1.378	1.338	1.300	1.267	1.237	1.211	1.187	1.163
7	1.600	1.510	1.440	1.386	1.340	1.300	1.264	1.233	1.203	1.176	1.149
8	1.629	1.534	1.456	1.392	1.344	1.300	1.264	1.229	1.198	1.165	1.135
10	1.661	1.558	1.473	1.409	1.355	1.306	1.264	1.222	1.187	1.152	1.120
12	1.686	1.578	1.490	1.420	1.361	1.308	1.261	1.219	1.180	1.143	1.109
14	1.708	1.592	1.502	1.429	1.366	1.309	1.260	1.214	1.172	1.136	1.100
16	1.726	1.610	1.513	1.433	1.368	1.309	1.255	1.208	1.165	1.127	1.090
18	1.741	1.623	1.525	1.441	1.370	1.308	1.252	1.203	1.160	1.118	1.080
20	1.755	1.632	1.531	1.446	1.372	1.307	1.250	1.199	1.152	1.109	1.070
	SPANWISE STATION $\frac{y}{b/2}=0.2$										
2	1.369	1.329	1.300	1.279	1.267	1.260	1.258	1.256	1.253	1.250	1.248
3	1.405	1.346	1.308	1.279	1.260	1.248	1.241	1.234	1.228	1.221	1.214
4	1.434	1.363	1.318	1.284	1.260	1.243	1.232	1.220	1.209	1.198	1.186
5	1.459	1.377	1.324	1.288	1.260	1.240	1.223	1.208	1.194	1.181	1.168
6	1.477	1.388	1.329	1.290	1.259	1.236	1.218	1.200	1.184	1.169	1.151
7	1.491	1.393	1.332	1.291	1.259	1.236	1.214	1.193	1.174	1.157	1.138
8	1.502	1.401	1.338	1.294	1.261	1.236	1.212	1.189	1.168	1.148	1.129
10	1.513	1.411	1.347	1.299	1.265	1.236	1.209	1.182	1.158	1.137	1.114
12	1.520	1.417	1.349	1.302	1.265	1.233	1.202	1.172	1.148	1.128	1.102
14	1.527	1.423	1.354	1.307	1.268	1.232	1.201	1.170	1.144	1.119	1.094
16	1.532	1.428	1.358	1.308	1.269	1.232	1.199	1.164	1.135	1.110	1.087
18	1.539	1.429	1.359	1.309	1.270	1.231	1.195	1.160	1.130	1.103	1.078
20	1.547	1.431	1.360	1.311	1.271	1.230	1.190	1.155	1.123	1.098	1.069
	SPANWISE STATION $\frac{y}{b/2}=0.4$										
2	1.217	1.190	1.178	1.172	1.172	1.171	1.170	1.169	1.169	1.168	1.168
3	1.220	1.191	1.176	1.166	1.161	1.160	1.159	1.158	1.157	1.156	1.155
4	1.223	1.192	1.173	1.162	1.156	1.151	1.149	1.148	1.147	1.146	1.145
5	1.226	1.193	1.172	1.159	1.149	1.142	1.140	1.138	1.136	1.134	1.133
6	1.229	1.193	1.171	1.155	1.145	1.138	1.132	1.128	1.127	1.126	1.125
7	1.229	1.193	1.170	1.152	1.140	1.131	1.124	1.121	1.120	1.119	1.118
8	1.229	1.193	1.168	1.150	1.138	1.128	1.120	1.116	1.113	1.111	1.110
10	1.228	1.192	1.167	1.148	1.132	1.121	1.113	1.108	1.104	1.102	1.100
12	1.228	1.192	1.166	1.145	1.125	1.111	1.107	1.102	1.099	1.094	1.090
14	1.228	1.191	1.161	1.136	1.116	1.104	1.100	1.096	1.090	1.087	1.082
16	1.228	1.189	1.158	1.131	1.112	1.101	1.097	1.091	1.086	1.081	1.075
18	1.228	1.186	1.152	1.129	1.111	1.100	1.092	1.087	1.080	1.076	1.070
20	1.228	1.182	1.149	1.127	1.110	1.098	1.089	1.083	1.078	1.071	1.065
	SPANWISE STATION $\frac{y}{b/2}=0.6$										
2	0.970	0.976	0.984	0.992	1.003	1.010	1.012	1.014	1.016	1.018	1.019
3	.950	.962	.975	.985	.996	1.004	1.011	1.018	1.023	1.030	1.038
4	.932	.948	.962	.978	.992	1.002	1.008	1.014	1.023	1.035	1.050
5	.920	.938	.953	.971	.988	1.000	1.008	1.015	1.024	1.038	1.053
6	.909	.930	.949	.966	.981	.993	1.002	1.013	1.024	1.039	1.056
7	.900	.920	.940	.959	.975	.989	1.000	1.012	1.024	1.039	1.054
8	.891	.916	.938	.956	.972	.988	.999	1.011	1.024	1.039	1.053
10	.881	.907	.929	.947	.961	.976	.992	1.008	1.023	1.039	1.052
12	.872	.901	.923	.941	.958	.972	.989	1.006	1.022	1.038	1.051
14	.868	.895	.918	.937	.953	.969	.986	1.003	1.019	1.035	1.049
16	.861	.888	.912	.931	.948	.966	.983	1.000	1.017	1.033	1.048
18	.858	.883	.906	.925	.944	.963	.981	.998	1.015	1.032	1.047
20	.851	.876	.898	.920	.940	.959	.978	.995	1.012	1.028	1.046
	SPANWISE STATION $\frac{y}{b/2}=0.8$										
2	0.615	0.678	0.712	0.731	0.740	0.745	0.746	0.746	0.747	0.747	0.748
3	.589	.659	.700	.726	.743	.754	.764	.772	.782	.790	.799
4	.568	.644	.691	.723	.746	.764	.781	.795	.806	.816	.824
5	.548	.632	.685	.720	.748	.769	.790	.808	.822	.834	.845
6	.531	.619	.675	.717	.748	.775	.800	.820	.838	.851	.862
7	.517	.609	.670	.713	.748	.778	.802	.827	.845	.861	.876
8	.504	.600	.663	.710	.748	.779	.808	.834	.854	.872	.886
10	.486	.585	.653	.704	.748	.783	.815	.842	.868	.887	.905
12	.472	.576	.648	.702	.748	.788	.821	.850	.877	.899	.919
14	.462	.569	.641	.699	.748	.789	.825	.858	.887	.911	.933
16	.456	.564	.638	.698	.748	.791	.830	.863	.894	.921	.944
18	.450	.559	.636	.698	.750	.796	.835	.870	.901	.930	.953
20	.444	.545	.629	.698	.753	.801	.842	.878	.909	.937	.962

TABLE II.—ADDITIONAL SPAN LIFT-DISTRIBUTION DATA—Continued

VALUES OF L_a FOR TAPERED WINGS WITH ROUNDED TIPS, $c_{l_{a1}}=\frac{S}{cb}L_a$

A \ c_t/c_s	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	SPANWISE STATION $\frac{y}{b/2}=0.9$										
2	0.378	0.465	0.508	0.525	0.531	0.534	0.535	0.536	0.537	0.538	0.539
3	.352	.447	.500	.528	.543	.552	.559	.564	.568	.571	.575
4	.331	.435	.495	.532	.554	.569	.581	.590	.598	.603	.609
5	.314	.424	.490	.531	.560	.583	.600	.613	.623	.630	.636
6	.300	.416	.487	.531	.565	.595	.615	.631	.643	.652	.659
7	.290	.410	.484	.535	.572	.603	.628	.646	.660	.671	.678
8	.282	.403	.481	.536	.579	.612	.638	.653	.673	.686	.696
10	.266	.383	.472	.541	.590	.628	.656	.679	.698	.712	.723
12	.253	.376	.469	.542	.597	.639	.669	.698	.718	.736	.751
14	.245	.370	.468	.545	.602	.648	.684	.715	.739	.759	.776
16	.239	.366	.468	.547	.609	.659	.698	.729	.756	.780	.801
18	.234	.367	.470	.552	.618	.669	.710	.743	.773	.800	.822
20	.231	.368	.473	.560	.625	.679	.722	.759	.791	.819	.846
	SPANWISE STATION $\frac{y}{b/2}=0.95$										
2	0.231	0.296	0.334	0.358	0.370	0.379	0.381	0.383	0.386	0.388	0.390
3	.209	.290	.339	.369	.389	.401	.407	.412	.416	.418	.420
4	.191	.286	.342	.378	.402	.420	.428	.434	.440	.444	.446
5	.176	.281	.344	.384	.415	.436	.449	.458	.463	.469	.471
6	.166	.278	.346	.392	.428	.451	.466	.475	.482	.490	.496
7	.155	.272	.346	.393	.438	.464	.481	.494	.503	.510	.515
8	.148	.261	.346	.403	.446	.475	.495	.510	.521	.529	.534
10	.138	.255	.346	.410	.460	.495	.520	.538	.553	.566	.575
12	.132	.254	.348	.419	.473	.511	.542	.566	.583	.598	.608
14	.129	.252	.349	.423	.482	.529	.563	.588	.609	.628	.640
16	.126	.252	.351	.432	.495	.546	.581	.610	.635	.655	.671
18	.122	.254	.357	.439	.503	.558	.598	.620	.658	.682	.702
20	.121	.258	.364	.449	.516	.569	.613	.648	.680	.707	.730
	SPANWISE STATION $\frac{y}{b/2}=0.975$										
2	0.132	0.172	0.207	0.239	0.263	0.272	0.274	0.277	0.279	0.281	0.282
3	.119	.166	.210	.250	.278	.289	.291	.294	.298	.300	.301
4	.107	.163	.214	.258	.288	.304	.308	.311	.315	.319	.322
5	.098	.158	.217	.269	.304	.320	.322	.328	.333	.338	.342
6	.089	.158	.219	.272	.314	.332	.340	.344	.350	.357	.361
7	.081	.158	.222	.278	.320	.342	.351	.359	.366	.373	.381
8	.077	.158	.228	.283	.328	.352	.363	.374	.383	.391	.400
10	.069	.158	.233	.295	.343	.373	.390	.403	.415	.428	.438
12	.068	.161	.242	.308	.360	.395	.413	.430	.448	.461	.473
14	.066	.163	.248	.320	.376	.418	.438	.458	.478	.495	.510
16	.064	.166	.255	.331	.394	.435	.463	.488	.510	.529	.546
18	.063	.169	.263	.346	.412	.461	.493	.518	.539	.560	.580
20	.062	.171	.271	.363	.435	.483	.515	.544	.570	.593	.615